

Case Study

Combined Heat and Power Schemes

CHP at the heart of Government

- *Energy costs reduced by £340 000 per year*
- *Carbon emissions reduced by over 1600 tonnes per year*
- *Improved security of supply*



Summary

Concern over global warming provided the impetus for the UK Government's agreement at Kyoto in 1997 to reduce greenhouse gas emissions by 12.5% over the period 2008-2012, compared to 1990 levels. Clearly, the Government's commitment to sustainability covers a range of interdependent, social, economic and environmental issues.

A significant contribution towards achieving these targets can be made through the effective use of combined heat and power (CHP), for which community heating (CH) schemes provide ideal applications. CHP schemes not only generate both heat and electricity but can also be used for summer cooling. CHP/CH has the added benefit of facilitating direct electricity sales.

Government is actively providing wide-ranging support for the development of CHP. It has made arrangements whereby Good Quality CHP is exempted from the Climate Change Levy. Furthermore, additional support is being provided through Enhanced Capital Allowances.

At the end of 2000 there was around 4700 MW_e of installed CHP capacity in the UK and Government has set a target of 10 000 MW_e by 2010. Of the existing installed capacity, schemes vary in size from relatively large scale through typical industrial schemes to small local authority sheltered dwelling schemes. Many of the schemes also benefit from additional revenues generated by the direct sale of surplus electricity.

Whitehall District Heating Scheme

The refurbished Whitehall District Heating Scheme (WDHS) is the Government's flagship CHP/CH scheme serving 10 Downing Street and a further 22 Government buildings in Whitehall, including the Ministry of Defence, Foreign and Commonwealth Office, Ministry of Agriculture, Fisheries and Food, Horse Guards, and HM Treasury.

It provides 34 GWh heat energy per year – enough to supply 3000 homes – and has surplus capacity for the connection of additional buildings.

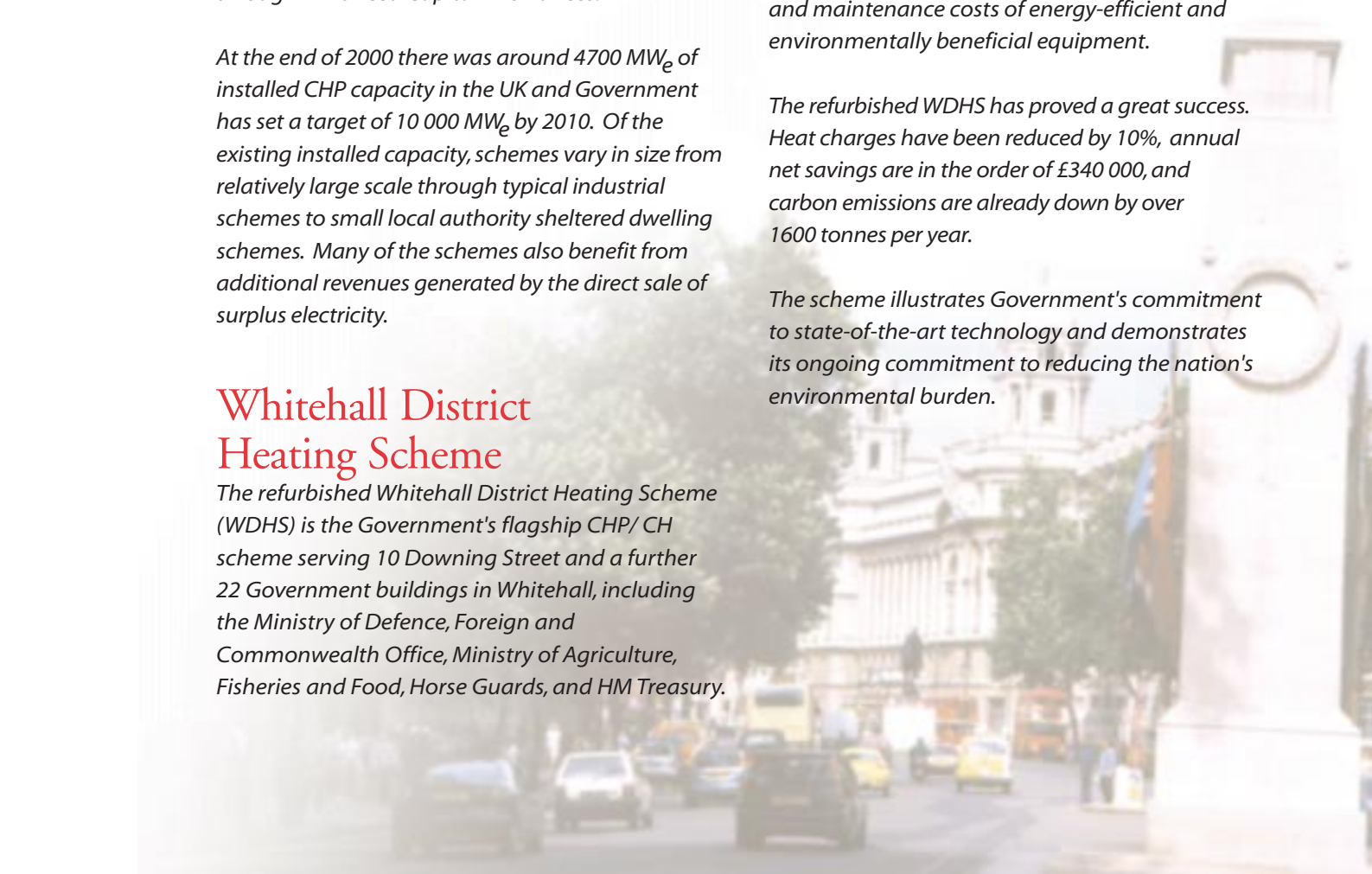
The system was originally designed in the late 1930s, and installed in the late 1940s/early 1950s, with three boilers operational by 1952. Distribution pipework reached its full extent in 1966, and comprises 24 km of underground heat mains.

In 1993, the Property Advisers to the Civil Estate (PACE) employed consultants to carry out a detailed feasibility study, because the original boiler plant was nearing the end of its useful life.

The decision to refurbish the scheme and to introduce CHP was made in light of the Government's clearly stated commitment to long-term sustainability in terms of energy use, environmental impact, economic viability and best value. This is best achieved by ensuring that projects are evaluated on the basis of Whole Life Costing (WLC). This takes into account the benefits, over the total life cycle, of the lower long-term operational and maintenance costs of energy-efficient and environmentally beneficial equipment.

The refurbished WDHS has proved a great success. Heat charges have been reduced by 10%, annual net savings are in the order of £340 000, and carbon emissions are already down by over 1600 tonnes per year.

The scheme illustrates Government's commitment to state-of-the-art technology and demonstrates its ongoing commitment to reducing the nation's environmental burden.



WDHS Aerial Plan



Introduction

Increasing concern over global warming is driving industrialised developed countries to take steps to reduce greenhouse gas emissions, principally carbon dioxide (CO₂). This is demonstrated by the UK's Kyoto commitment to reduce global warming gases by 12.5% over 1990 levels by 2008-2012.

A significant stride towards achieving these targets can be made through the effective use of CHP, for which CH schemes provide ideal applications. CHP operating with CH schemes can provide a reliable, competitive, easy to maintain and efficient means of providing heat to blocks of flats, social housing, commercial buildings and, as illustrated in this Case Study, public buildings. CHP is widely utilised in the industrial sector and in the healthcare, hotel and leisure sectors.

At the end of 2000 there was around 4700 MW_e of installed CHP capacity in the UK. Schemes vary in size from relatively large scale (200 MW_e) through typical industrial schemes of around 40 MW_e to small local authority sheltered dwelling schemes of 200-300 kW_e.

CH supplied by CHP is therefore an excellent way to:

- provide low-cost heat, electricity and cooling
- reduce primary energy use and emissions of greenhouse gases
- maintain a reliable level of supply.

With its ambitious CO₂ commitments, the Government is leading the way and showing confidence in this state-of-the-art technology. The WDHS illustrates the energy and cost saving potential and demonstrates the Government's commitment to lead by example. This Case Study is written for decision makers in both the public and private sectors. It describes the approach adopted when upgrading the Scheme and the benefits that followed.

The Whitehall Scheme won the 1999 Combined Heat and Power Association's 'CHP in Buildings' award in recognition of the benefits of bringing CH/CHP right to the environmental heart of Government.

What is Community Heating ?

Community heating (CH) involves the use of large centralised boilerplant (or other heat sources) to heat a number of discrete premises. Heat (usually in the form of hot water) is distributed from the central boilerplant to the CH system provider's customers via heavily insulated underground pipes.

CH systems can range in size from the energy linking of two or three buildings, through to city-based networks that serve whole areas of cities, as is the case in Nottingham, Sheffield, Southampton and London's Barbican.

By utilising central boilerplants, CH systems can benefit from competitive fuel purchasing and can also utilise alternative energy sources such as bio-fuels or CHP.

Particular areas where CH has proven effective are:

- dense city centre developments
- shopping centres
- business parks
- major individual developments
- high-density residential developments.

What is CHP?

Combined heat and power (CHP) is the simultaneous generation of heat and power in a single process.

When electricity is generated, only part of the input energy is converted into electricity, typically 30-50%. The remainder of the energy consumed by the generation process is usually dissipated via cooling towers as waste heat. CHP plant operates at much higher levels of efficiency – typically 60%-80% – where a suitable use for this waste heat can be found.

In addition to providing normal power and heat, CHP can produce electricity for use during a mains failure. It provides, therefore, an ideal source of stand-by power for essential loads. When connected to a CH system it can also provide district cooling via absorption chillers, as on the Barbican Estate. Surplus electricity can also be sold directly to consumers through dedicated cables or by utilising the local electricity supply network.

The Government is actively promoting CHP through a range of measures to incentivise Good Quality CHP. Measures introduced from 1 April 2001 include:

- exemption from the Climate Change Levy for direct sales to customers
- exemption from business rating for CHP power-generating plant and machinery and associated accessories
- eligibility for Enhanced Capital Allowances offering tax incentives to firms investing in energy-saving technologies.

For details of what qualifies as Good Quality CHP, contact www.chpqa.com or the Government's Environment and Energy Helpline on 0800 585794.

Whitehall District Heating Scheme

The WDHS was conceived and designed in the 1930s to replace the inefficient heating of Whitehall Offices by open coal fires. Installation of boilers commenced in the 1950s and the full CH scheme was up and running by 1966. Over the past 30 years, the central boiler plant has been upgraded a number of times to improve performance and economy.

The CH scheme supplies 23 Government buildings through some 24 km (15 miles) of distribution pipework routed through a network of underground tunnels.

Buildings included on the scheme are:

- Downing Street
- Ministry of Defence
- Foreign and Commonwealth Office
- Ministry of Agriculture, Fisheries and Food
- Horse Guards
- HM Treasury.

To put the size of the system into context, the WDHS supplies sufficient heat (33.9 GWh per year) to supply 3000 semi-detached houses. Heat losses from the distribution pipework amount to about 2 GWh, ie 6% of the total heat generated, which is similar to comparative schemes of the same vintage.

Upgrading the Scheme

In 1993, PACE, owners of the scheme since 1990, employed consultants to carry out a detailed condition survey of the system. This identified that, while the distribution pipework was in satisfactory condition and would last for another 15 years, the central plant was becoming inefficient and nearing the end of its useful life.

A full option appraisal of possible systems was carried out. In particular, initial consideration was given to installing self-contained boiler plant in individual buildings – a decentralised system. However, a cost analysis of this revealed that it would require significantly higher capital investment when compared to installing new centralised boilers. This was due, in part, to the cost of providing back-up boilers for each building (this capacity is pooled in the WDHS) and the provision of exhaust flues in each building. Moving to individual boiler plant would also have increased average energy costs to the individual buildings by 30%. The increase in energy costs from decentralised boilers would have been primarily due to less attractive gas tariffs when purchasing on an individual building basis rather than collectively.

It is important that this level of analysis is undertaken whenever refurbishment of a CH scheme or individual boiler system is being considered – as far too often CH systems are removed without due consideration of their benefits. The 'Guide to community heating' (GPG 234) provides extensive information on appraising CH.

Options, Funding and Tender Invitation

Once the decision had been made to retain the CH scheme, the next decision was to determine what plant would provide the most cost-effective and reliable source of heat. To this end CHP became an obvious candidate.

A number of different sizes and combinations of CHP were reviewed and, when compared with the non-CHP option of purely heat-only boilers, all showed significant reduction in annual energy cost together with a reduction in total net present cost. Several funding options were considered, including Private Finance Initiative (PFI) funding. However, as the scheme was for Government Estates, the capital investment was obtained from Treasury capital.

PACE tendered the project and the contract was awarded to ELYO (UK) Ltd in December 1995. Parsons Brinckerhoff were employed by ELYO (UK) Ltd to design and manage the installation of the plant for which the final capital cost was £7.82 million (this cost included not only the CHP system but the costs of new 'top-up' boilers and other equipment).

Funding Options

There are various ways in which funding can be attracted for CHP/CH installation, operation and maintenance. The most common being:

- *outright purchase from internal budgets*
- *commercial loans*
- *grant-aided funding*
- *PFI funding*
- *contract energy management (CEM)*
- *energy services companies (ESCOs).*

Through PFI, CEM and ESCOs, specialist companies provide funding and management expertise to help finance the installation. The companies will then operate and maintain the system on behalf of the client and share in the savings achieved.

Whole Life Costing

Decisions relating to the selection of the most appropriate heating systems require very detailed consideration to ensure that the final option selected is properly based on technical, economic and environmental grounds.

It is not necessarily always the case that the lowest initial cost option represents the best value, in terms of either money, technical capability or environmental impact. The process of WLC provides a method whereby the various options and solutions can be properly compared in financial terms based upon costs and revenues which occur over the life of the systems rather than simply on initial capital cost.

Application of the WLC procedure certainly involves considerably more time and effort at the design stage but conversely, the benefits

derived are likely to be substantial and will continue during the whole lifetime of the initial investment.

Simple payback calculations have been shown to be inadequate for appraising CH because they do not take into account project lifetimes, individual system replacement costs or environmental costs. Project lifetime has a critical bearing on the results of the economic appraisal because the longer the period of years included in the cashflow analysis, the higher the Net Present Value (NPV) or Internal Rate of Return (IRR). This is of particular importance where one heating alternative has a longer assumed 'life' than another, as is the case with CH.

Further information on how to appraise CH schemes is contained in the 'Guide to community heating' (GPG 234) – see page 12.

Installed System

The introduction of CHP into the WDHS required replacement of all of the existing boilers with a combination of CHP and new heat-only boilers. The installed system comprises a single 4.9 MW_e Alstom Typhoon gas turbine, with heat output of 8 MW via a waste heat boiler. The gas turbine is supported, when necessary, by four conventional boilers each rated at 5.8 MW which provide backup only in extreme weather and act as a stand-by supply of heat in the event of maintenance outage on the turbine/waste heat boiler.

Energy Usage and Costs

The CHP turbine and boilers operate on a dual fuel supply allowing cheaper, interruptible gas to be used, which may be supplemented by oil during peak periods. However, during the surveyed period (1998/1999), no oil was used. The CHP and boilers use around 120 556 MWh of gas per year.

The comparison seen in table 1 shows that CHP provides a net saving of £344 000 per year over the original heat-only boilers. This annual saving is used to repay the cost of the CHP and, importantly,

to provide a lower heat price to the users of the WDHS. The benefit from this CHP scheme will increase further in the future as the CHP scheme will have the opportunity to sell Climate Change Levy free electricity direct to the Ministry of Defence.

System Expansion

The system has been designed with surplus capacity to accommodate additional buildings that can be connected in the future when their existing heating systems require major refurbishment or replacement.

Table 1 – The CHP scheme as opposed to the original heat-only boilers

	Original boilers	CHP with top-up boilers
Fuel cost	£337 882 ^(a)	£768 000 ^(c)
Electricity cost	£100 100 ^(b)	£(807 500) ^(d)
Maintenance costs	£530 000	£663 000
Total cost	£967 982	£623 500

- (a) Cost of boiler fuel to provide 35.9 GWh of heat at boiler efficiency of 68%
 (b) Cost of electricity used by the scheme, eg for pumping
 (c) Cost of CHP fuel plus 'top-up' boiler fuel
 (d) Electricity income from sales of surplus electricity to the Ministry of Defence and the grid

Connections to Secondary Systems

The distribution pipework supplies high-temperature hot water (HTHW) at 160°C to each of the buildings on the system. The supply is metered at the point of entry into each building, and the readings are transmitted to the central control room where they are processed on a PC-based data collection system. The data is used as the basis for charging customers for the heat used. The secondary systems are beyond the control of the WDHS and each building, or customer, is responsible for their own use of the heat after it enters their building.

Customers vary in their specific method of converting the delivered HTHW into low-temperature hot water (LTHW) for distribution around their buildings for space heating and domestic hot water use. However, the most common method is via indirect plate heat exchangers providing complete hydraulic separation between the WDHS system and individual installations.

Norman Jones, PACE



'Government users are pleased with the results of the refurbishment project and are now starting to benefit from both lower energy costs and the system's flexibility.'

Norman Jones, PACE

The radiator systems within the buildings are supplied with LTHW via non-storage calorifiers that are served by the plate heat exchangers. Some installations are controlled by a building management system (BMS), some by optimisers, and some by simple time switches.

Domestic hot water is also generally provided through an indirect system incorporating a plate heat exchanger and storage calorifier.

Operation and Maintenance

During the heating season, the CHP plant operates as the lead boiler to satisfy the heat demands of the WDHS system, the four heat-only boilers are then sequenced on in response to the increasing heat demands. The net electricity produced by the turbine (that generated minus that used by the gas compressor) is used within the boiler room, eg for pumping (8%), and Ministry of Defence building (14%) with any surplus exported (78%).

Typical plate heat exchanger installation



At present during summer, the turbine operates during on-peak hours only to provide electricity at below purchase costs.

Maintenance of the CHP plant includes specific requirements such as a replacement of the turbine shaft every three years and maintenance of the CHP generator and electrical services. The maintenance cost of the CHP plant amounts to £130 000 per year. The cost of maintaining the WDHS distribution system, excluding CHP plant, is £530 000 per year. The maintenance of the CHP plant and the purchase of fuel for the unit is undertaken by ELYO (UK) Ltd under an energy services agreement with PACE.

These costs are passed on to the customers through their standing charges and are based on a requirement for six full-time staff to operate the system and undertake routine and planned maintenance of all associated plant, distribution systems and pipework up to the point of entry to the customers' buildings. Major maintenance to the plant and distribution pipework is carried out during the summer close-down period.

Benefits for Users

Connection to the WDHS provides substantial benefits for its users. Customers have a security of supply that is afforded by the central system which is manned around the clock to ensure that their requirements are met.

The individual plate heat exchangers operate as a direct replacement for boilerplant yet are significantly more compact, taking just one-tenth of the space. Plate heat exchangers require no fire protection, fluing or ventilation, making their installation simple and giving the users much more freedom of location. Furthermore, compared to conventional boilerplant, the plate heat exchangers are silent in operation and have substantially lower maintenance requirements.

Environmental Benefits

As well as the financial benefits, the CHP scheme provides significant environmental benefits. These benefits are seen largely as a reduction in gaseous emissions for the UK as a whole.

Table 2 shows that the CHP solution provides a reduction in carbon emissions of over 1600 tonnes per year over the original heat-only boiler system.

Table 2 – Carbon production (tonnes)

	Original boilers (tonnes)	CHP with top-up boilers (tonnes)
Fuel	2745	6240
Electricity	421	(4703)
Total CO₂	3166	1537

CHP gas turbine unit



Central control room

‘Our major buildings have been served by the Whitehall District Heating Scheme for many years and we are aware that significant improvements have been made to the central plant in recent years. The system remains quietly efficient providing us with heat and hot water on demand throughout the winter.’

John Gildea, FCO

Conclusions

The incorporation of CHP into the WDHS represents a positive step by the Government in leading by example. The scheme illustrates the Government's commitment to state-of-the-art technology and demonstrates its ongoing commitment to reducing the nation's environmental burden.

The Scheme shows how the use of a CH network can extend the benefits of CHP to building sectors which are not usually suitable for CHP, for example, offices.

The Scheme also demonstrates that where there is existing CH infrastructure, the refurbishment of the Scheme to include CHP is likely to be not only the most environmentally friendly choice but the most economic option.



Further Information and Advice

CHP Club

The CHP Club (www.chpclub.com) is the Energy Efficiency Best Practice programme's (EEBPP's) gateway to the support services users need when making any CHP investment decision. It is a user-focused forum where CHP users and potential users can access information, exchange experiences, ask questions and share good practice. Members of the Club have access to a range of complementary benefits:

- the Manager's Guide to Combined Heat and Power Systems
- an Internet Forum
- information about international CHP best practice
- a Club Newsletter
- a network of CHP 'Champions'
- free consultancy advice
- a major annual event.

In addition, further information on CH schemes can be found in other EEBPP publications that are obtainable from the Government's Environment and Energy Helpline on 0800 585794.

These publications include:

- Guide to community heating (GPG 234)
- Community heating – a guide for housing managers (GPG 240)
- Community heating in Sheffield (GPCS 81)
- Community heating in Nottingham: an overview of a rejuvenated system (GPCS 312)
- The use of CHP in community heating schemes – four case studies (GPCS 370).

Other Sources of Information on CHP

Combined Heat & Power Association
Grosvenor Gardens House, 35-37 Grosvenor Gardens
London SW1W 0BS
Tel 020 7828 4077
www.chpa.co.uk



CHP Club is an initiative of the Energy Efficiency Best Practice programme. Further help and advice is available online through www.chpclub.com or by telephone through the Environment and Energy Helpline on 0800 585794.